AIR QUALITY DEGRADATION IN THE MEDITERRANEAN URBAN REGIONS FROM ANTHROPOGENIC AND NATURAL PARTICULATE MATTER

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INTRODUCTION

Several urban areas in the Greater Mediterranean Region are not capable of meeting the imposed EU standards on ozone and particulate matter. This is attributed mainly to the climatic conditions in the Region and to the contribution of natural sources. Climatic conditions contribute mainly to the formation of ozone and particulate matter of anthropogenic origin, while natural sources contribute to the formation of total PM. Photochemical reactions and atmospheric thermodynamic processes are affected by high amounts of anthropogenic particles such as sulfates and nitrates as well as episodes of high Saharan dust concentration. Advanced modeling techniques, as complementary tools to observations, are implemented world-wide for the identification of production, transport, transformation and deposition patterns, as well as for the understanding of the aerosol cycle in the atmosphere and its potential impacts and interactions with other pollutants.

In this presentation two advanced atmospheric modeling systems and one photochemical modeling system are used together with available air quality measurements, in order to simulate atmospheric conditions and assess the air quality in urban regions in the Mediterranean Region. Sensitivity tests concerning the production of fine particulate sulfate in several locations in the Mediterranean Region, showed some interesting, characteristic results for each location. Interactions between anthropogenic and natural particulate matter are under investigation, such as the influence in the radiation scheme as a primary target and the results in the aqueous phase formulation of particulate as a secondary target. The results of this work are an important step towards the understanding of the mechanisms that influence the state of the air quality of several urban areas, mostly influenced by high amounts of particulate matter in the atmosphere.

MODEL DESCRIPTION

A short description of the modeling systems used for performing simulations is provided below.

The SKIRON/ETA is a modeling system developed at the University of Athens from the Atmospheric Modeling and Weather Forecasting Group (Kallos et al, 1997, Nickovic et al, 2001). It has enhanced capabilities with the unique one to simulate the dust cycle (uptake, transport, deposition).

RAMS (Regional Atmospheric Modeling System) is considered as one of the most advanced atmospheric models. Detailed information about RAMS model can be found in Cotton et al (2003).

The Comprehensive Air Quality Model with Extensions (CAMx) (Environ, 2003) is an Eulerian photochemical model that allows for integrated assessment of air-pollution over many scales ranging from urban to super-regional (http://www.camx.com). CAMx has also model structures for modeling aerosols, processes that are linked to the CB4 gas phase chemical mechanism, science modules for aqueous chemistry (RADM-AQ) inorganic aerosol thermodynamics/partitioning (ISORROPIA) and secondary organic aerosol formation/partitioning (SOAP).

ANTHROPOGENIC AND NATURAL PARTICULATE MATTER

The paths and scales of transport and transformation of air pollutants in the Mediterranean Region have been identified in previous work carried out at the framework of various EU projects (Kallos et al, 1997, 1999) as shown in Figure 1.

Anthropogenic gases and particulate matter as well as natural aerosol like desert dust are the subject of modeling studies in conjunction with measurements of pollutants. Ozone is a well known secondary pollutant, which has been the primary target of several studies during the last 20 years. Ozone formation, destruction, transport and deposition patterns have been identified in various projects in the past. During the last years, a great number of studies focus on the important role of aerosols in the air quality of a specific area, due to the potential impact on human health and ecosystems (di Sarra et al, 2001, Rodriguez et al, 2001).Today the scientific interest focuses on the patterns that characterize aerosols in the atmosphere as well as the interaction between gases and particulate matter mainly of small sizes.

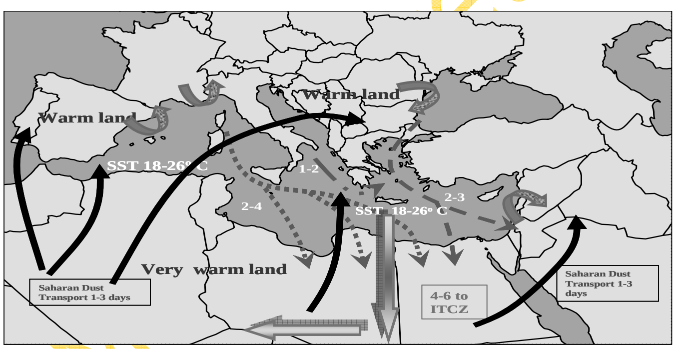

Figure 1: *Characteristic paths and scales of transport of air masses in the Mediterranean Region.*

Particulate sulfate production and transport is part of an on-going research using advanced modeling systems. In order to identify the paths and transformation of SO_2 to particulate sulfate, the sulfate ratio was calculated within the code of CAMx model. Sulfate ratio has been used in previous studies (Luria et al, 1996) to define the chemical age of air masses, based on measurements of sulfur dioxide and particulate sulfate. Sulfate ratio is characterized as the ratio of sulfate concentration to total sulfur concentration (meaning both SO_2 and particulate sulfate), leading to a dimensionless value from zero to unity. According to Luria (1996), the higher values for sulfate ratio (greater than 0.1) correspond to aged air masses, and the closer the ratio is to unity, the older the air mass and the longer its travel distance. CAMx model code was modified in order to calculate an average sulfate ratio for each hour of the simulation, using meteorological fields either from RAMS or from SKIRON/Eta model.

In addition to the anthropogenic produced aerosols, such as sulfates and/or nitrates, desert dust contributes significantly to the air quality degradation, due to the episodic character of increased desert dust concentrations. In general, air pollution episodes originated from anthropogenic activities occur together with desert dust transport episodes, because of the prevailing synoptic conditions favorable to dust transport (ahead of a trough or behind an anticyclone in the Mediterranean Region). Such synoptic conditions are most of the times associated with stable atmospheric conditions and stagnation (transport of warm air masses aloft that suppress vertical developments like updraft and convergence zones). The strength and the frequency of occurrence of the Saharan dust episodes define the annual deposition amounts and patterns of aerosols to a high degree, alternating the mean annual values (Papadopoulos et al, 2003). This leads to the fact that long-term modeling and measurement data are essential in understanding the synergetic effects of sulfates and desert dust in the atmosphere of the Mediterranean Region.

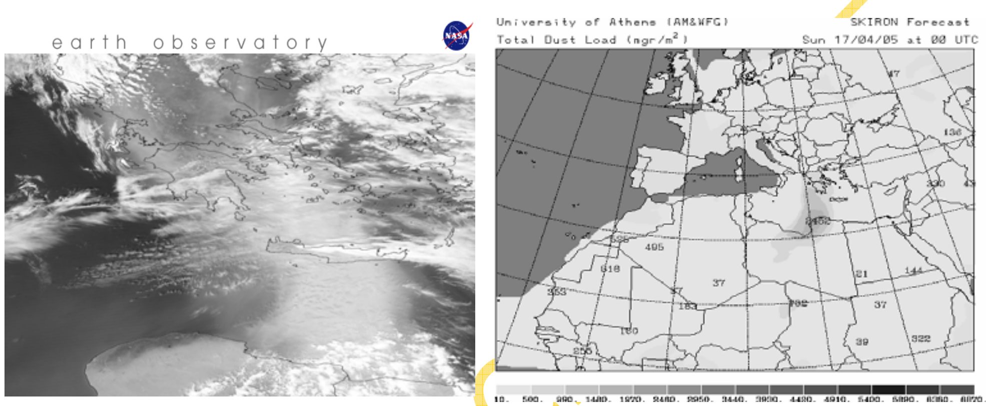

Figure 2: *Saharan dust episode for April 17, 2005.* *<u>Left:</u>* *Dust over Greece, picture taken from NASA/GSFC satellite (2005/107 - 04/17 at 11:40 UTC).* *<u>Right:</u>* *Total dust load as simulated from SKIRON/Eta dust modeling system.*

The knowledge gained from years of modeling atmospheric and photochemistry processes, provided the ability for forecasting weather phenomena and air pollutant concentration in the Mediterranean Region focusing on urban areas. Since January 2000, the SKIRON/ETA model runs operationally covering the Mediterranean Region, providing 3-day forecasts of dust load and deposition (http://forecast.uoa.gr), among other meteorological parameters. The ozone forecasting system applied for the Mediterranean Region runs operationally since July 2004, for the Athens Olympic Games (http://forecast.uoa.gr). The system is based on CAMx photochemical model and utilizes meteorological fields from SKIRON and RAMS in order to produce long-range transport fields of ozone and particulate for Europe and the Mediterranean Region. The operational use of atmospheric and air quality models provides the opportunity to study the photochemical activity, particle formation and transport in various scales, from mesoscale to regional, as shown in Figures 2-4. The effort for producing reliable air quality predictions is a well-based and on-going task. Continuous research and sufficient measurements of air pollutants should aid this effort into the future of accurate predictions.

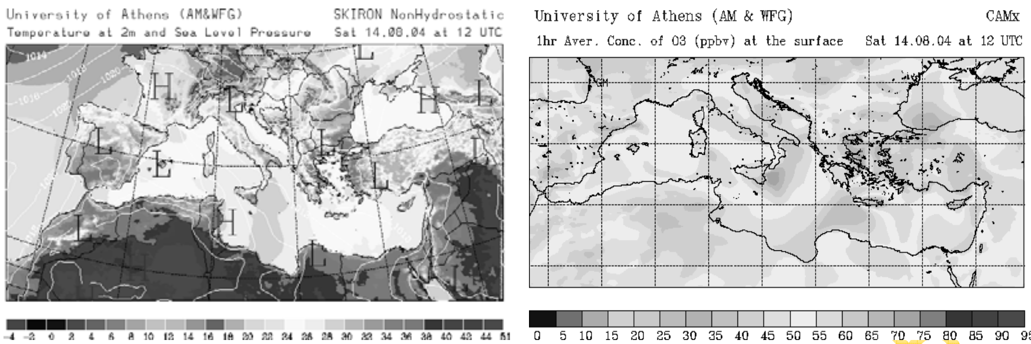

Figure 3: *Regional weather (left) and air quality (right) forecasts (ozone) for the Mediterranean Region.*

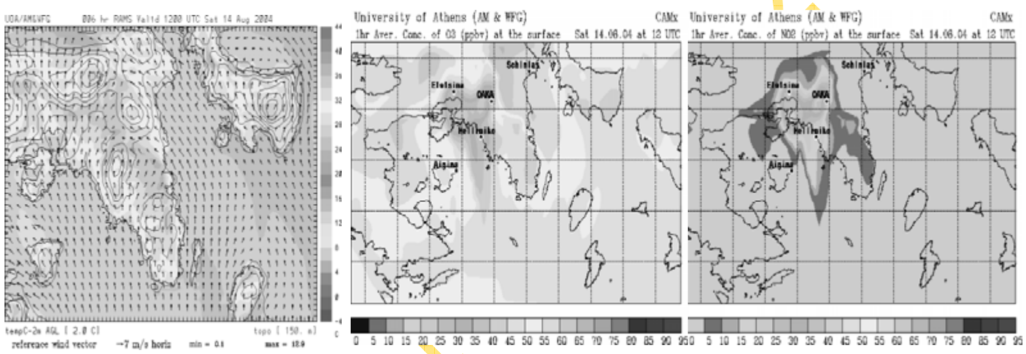

Figure 4 *High resolution weather forecast from RAMS model (left) and air quality (middle, right) forecasts (O_3, NO_2) for Athens Olympics (summer 2004).*

CONCLUSIONS

The present study summarizes the multi-year research modeling studies for identification of the characteristic spatial and temporal scales of air pollutant activity along the previously defined main transport routes over the Mediterranean Region. Air quality degradation in the area is influenced by photochemical pollutants like ozone as well as aerosols such as particulate sulfate and desert dust. Several urban areas in the Region are not capable of meeting the imposed EU standards on particulate matter, due to the uncertainties in the contribution of natural PM's and the synergetic effects on natural and anthropogenic aerosols in the atmosphere. Some concluding remarks follow:

The sulfate ratio sensitivity tests performed in this work showed results similar to those of Luria (1996), confirming the long range transport paths of sulfur towards the Middle East coast, during summer. Usually, high concentrations of sulfate, nitrate and other particles of anthropogenic origin, are associated with transport of desert dust due to the formation of stable atmospheric conditions. There are indications that the multi-scale transport and transformation processes might have significant climatic impacts.

The above conclusions are a result of the on-going research based on using modeling techniques for assessing the air quality over specific areas. Modeling tools are subject to continuous development in order to eliminate as many errors as possible. Thus, the on-going development has showed the way to producing real time forecasts of air pollution episodes in different scales: from urban to regional. The operational use of advanced atmospheric and air quality models has provided reliable predictions of several air quality episodes in the Mediterranean Region. Nevertheless continuous research and sufficient measurements of air pollutants should aid this effort into the future of accurate predictions.

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